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Elemental Analysis of As-Build Concrete and Aluminum for the National Ignition Facility and Their Effect upon Residual Dose Rates

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GDMS measurements provide final material compositions, which are compared to expected values. Finally, the calculations are repeated with the measured compositions and the residual dose rates are compared to the expected levels.

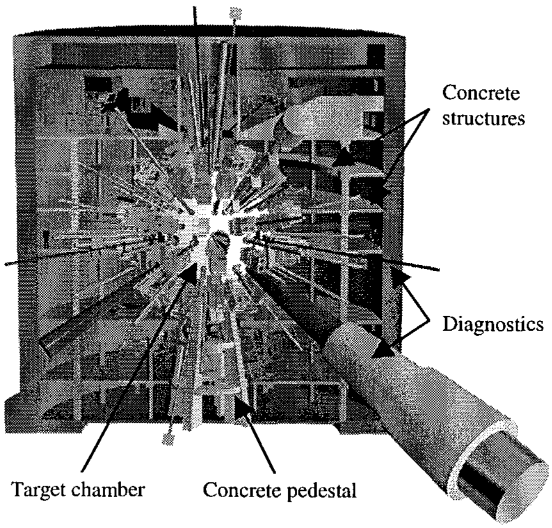

Fig. 1. A cross section of the NIF Target Bay reveals the target chamber, its concrete pedestal, and structures within the building.

3-D neutronics calculations have been performed using the TART98 Monte Carlo transport code.[2] Activation calculations have been completed with the ACAB activation code and the FENDL/A-2.0 activation cross section library.[3-4] These codes have been benchmarked against experiment as well as against other codes.[5-6] Activation calculations assume that the annual yield is produced in sixty equally spaced shots of 20 MJ yield each. To account for build-up on long-lived radionuclides, 30 years of operation is assumed.

GDMS is a relatively new technique for elemental analysis. It is a rapid, direct method that provides quantitative results. Samples are exposed to an argon plasma (+1 kV). Sputtering occurs and atoms diffuse into a self-sustaining negative glow, where they are ionized. These ions are accelerated to 8 kV and pass into magnetic sectors where they are mass analyzed.

4. Results

Elemental compositions and the residual dose rates that would result are presented for early NIF concrete studies, current "as-built" concrete, and the Al-5083 target chamber.

4.1. Expected NIF concrete

Early NIF concrete studies focused on the main constituents and only a limited set of impurities. Elemental analyses were conducted via inductively-coupled-plasma mass spectrometry (ICP-MS) and x-ray fluorescence (XRF). Using these methods, the composition shown in *table I* was developed. For this composition, key contributors to the residual dose rate include ^{56}Mn (dominates from minutes to ~ 12 hours after a shot), ^{24}Na (dominates from ~ 12 hours to 10 days), ^{46}Sc, ^{54}Mn, and ^{60}Co (important contributors beyond 10 days).

Table I. ICP-MS and XRF techniques were used to specify the NIF concrete composition.

Element	Wt. %	Element	Wt. %
H	0.79	B	9 ppm
O	59.26	Na	0.71
Mg	0.41	Al	2.61
Si	18.52	S	0.41
K	1.37	Ca	14.71
Sc	1 ppm	Ti	0.10
Mn	0.02	Fe	1.08
Ni	20 ppm	Cu	10 ppm

The majority of these radionuclides are produced via reactions with high-energy neutrons, and thus, a boron additive would not help very much. The low-activation aspects of this concrete arise from the fact that the sodium, aluminum, manganese, iron, and nickel contents are quite low. This is particular to the limestone aggregate that has been selected. This result agrees with previous work by Oishi et al. for work on the TFTR concrete igloo.[7]

4.2. As-built NIF concrete

GDMS testing of concrete samples has begun. Thus far, samples have been tested from the low-activation concrete pours for the -21'-9" slab, -3'-6" slab, and target chamber pedestal. Samples have been collected for the 17'-6" slab, 29'-6" slab, and 40'-0" slab. Samples will be gathered from the upcoming 50'-6" slab and the gunite shielding for the target chamber (two proposed gunite mix designs were tested; the second was approved for use).

GDMS results have shown a far wider array of impurities than noted during ICP-MS testing. *Figure 2* shows the composition from the -21'-9" slab. In all, 64 elements were identified. Five elements were present at levels of at least 1 wt%. An additional 5 were present between 100 wppm and 1 wt%, 38 were between 1 and 100 wppm, and 11 were at levels of < 1 wppm.

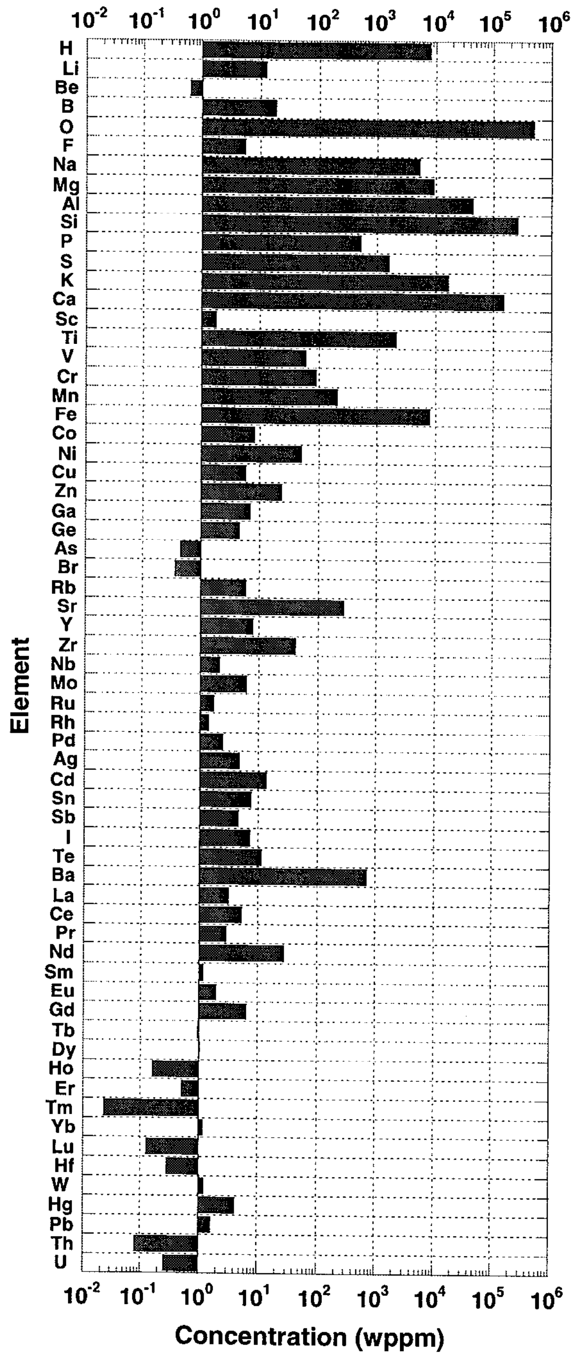

Fig. 2. The elemental composition for the -21'-9" elevated slab concrete includes many impurities.

To determine the potential effect from these impurities, neutron transport and activation calculations were repeated using the measured concrete composition. *Figure 3* shows the contact dose rate from the assumed composition, the measured composition, and the ratio of the two results as a function of time. Little difference is observed until long decay times when ^{60}Co dominates due to the presence of 8 wppm of cobalt. Additionally, 2 wppm of europium produces ^{152}Eu, which is responsible for 45% of the contact dose rate at a time of 3 years after the final shot.

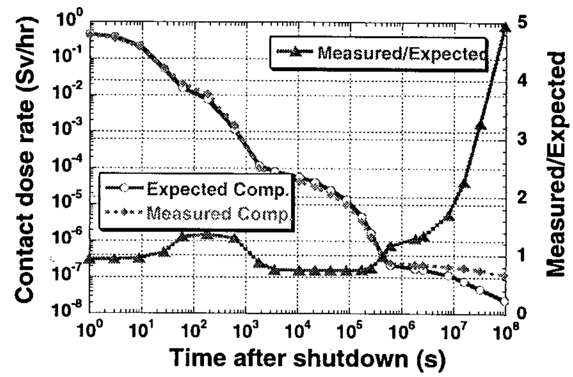

Fig. 3. Good agreement is observed between the contact dose rates calculated with the measured and expected concrete compositions.

Similar results were observed for the concrete at the -3'-6" elevation. These are shown in *figure 4*. Again, the contact dose rate is elevated due to ^{60}Co and ^{152}Eu. The cobalt impurity fell to 3 wppm, but europium increased to 3.7 wppm. After 3 years of decay, the contact dose rate would still exceed the 0.125 μSv/hr goal for unrestricted reuse. When one considers the yields that are expected, photon transport, and equipment that has not been included in the neutron transport model, however, the actual dose rate will fall by 5-10×, and the goal should be achieved easily.

4.3. As-built NIF target chamber

GDMS analysis of Al-5083 samples revealed a favorable composition for the NIF target chamber. *Figure 5* shows the contact dose rates for the expected and measured compositions. The manganese, iron, and zinc contents are lower than anticipated (the high end of the range was assumed). Thus, the ^{54}Mn, ^{56}Mn, and ^{65}Zn inventories are lower than expected. ^{60}Co production was higher than expected due to a higher level of copper impurity.

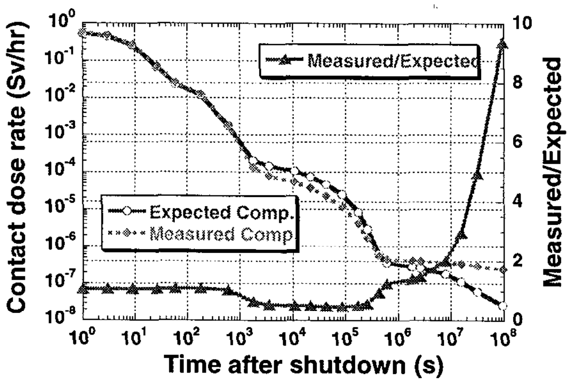

Fig. 4. Although good agreement is seen at early decay times, the presence of 3.7 wppm europium in the -3'-6" concrete leads to a contact dose rate that is ~ 9× higher than expected after 3 years of decay.

5. Conclusions and future work

GDMS testing of samples from some key NIF concrete pours has been completed. The results suggest that concrete impurities may lead to higher than expected contact dose rates after long decay times, but the difference is not expected to lead to a change in the ultimate disposition of the facility upon decommissioning. In general, dose rates from concrete structures are dwarfed by those from other equipment, so the higher than expected dose rate will not affect worker doses.

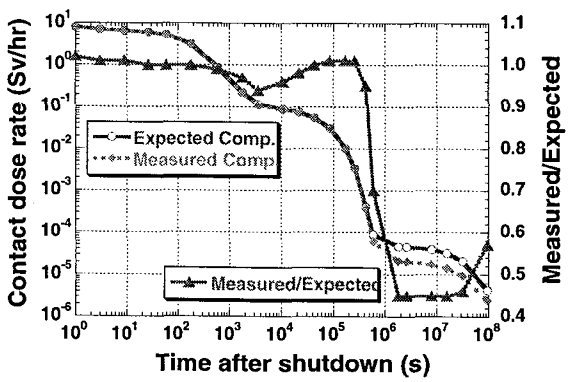

Fig. 5. The Al-5083 composition results in a lower than expected contact dose rate at key times.

Al-5083 target chamber samples show lower than expected use of manganese and iron alloying agents, and thus, lower dose rates at times of interest for worker doses.

Samples from upcoming construction activities will continue to be analyzed, and ultimately, results will be incorporated into occupational dose estimates for operation and decommissioning of the NIF.

Acknowledgments

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